91602
new 82-10

ontario hydro
research division

COMPLIMENTARY COPY
Please Credit Ontario Hydro Research if
Reproduced in Whole or in Part

MCCOWAN ROAD VEGETATION STUDY
THE DEVELOPMENT OF WOODY VEGETATION IN THE SECOND YEAR POST-CLEARING

Report No 87-113-K

D.G. Brown
Biologist
Biological Research Section
Chemical Research Department

ABSTRACT

The invasion of a simulated right-of-way by woody species is described at the McCowan Road research site. A rapid proliferation of small shrubs has occurred in the two years following the clearing of the site. Populus tremuloides (trembling aspen) has become the most abundant of the incompatible trees, with a density of 5.16 stems/m^2. Acer saccharum (sugar maple) (3.69 stems/m^2) and Fraxinus americana (white ash) (2.92 stems/m^2) also contribute substantially to the tree layer. The stems of stump sprouts and root suckers were considerably taller than the tree stems originating from seeds. However, seedlings were more numerous for all the tree species except P. tremuloides.

Ordination analysis of the vegetation indicated that a small group of shrub species was negatively associated with the incompatible tree species, and the implications of this for vegetation management is discussed.

job	file	date	report no.
34-555-031	834.1	July 1, 1987	87-113-K

91602
new 82-10

ontario hydro
research division

EXECUTIVE SUMMARY

MCCOWAN ROAD VEGETATION STUDY. THE DEVELOPMENT OF WOODY VEGETATION IN THE SECOND YEAR POST-CLEARING

D.G. Brown
Biological Research Section
Chemical Research Department

The vegetational management techniques used on Ontario Hydro transmission rights-of-way must be capable of controlling tall-growing (incompatible) species. The development of an integrated control policy is complicated by the fact that the incompatible vegetation develops from two sources with contrasting growth characteristics. Stems developing from ineffectively treated stumps (root suckers or stump sprouts) have higher growth rates and survivorship potentials than stems developing from seeds. Seedlings are, however, more numerous and it is important to determine if their increased numbers outweigh their slower growth rates.

A survey of the woody vegetation at the McCowan road right-of-way site was undertaken in the second year post-clearing to investigate the source of incompatible stems. The total tree density was 13.7 stems/m^2, of which 55% were root suckers or stump sprouts. On an individual species basis, seedlings of Acer saccharum (sugar maple), Fagus grandifolia (beech), Fraxinus americana (white ash) and Tilia americana (basswood) were more numerous and made a larger contribution to the canopy height than sprouts of these species. However, the canopy was dominated by root suckers of Populus tremuloides (trembling aspen), in terms of both number and height.

The shrub layer has also increased considerably in the time since the area was cleared (fall of 1984). An analysis of the community structure using two different ordination techniques indicated that a group of shrub species (Rubus idaeus (raspberry), R. occidentalis (black raspberry), Prunus pensylvanica (pin cherry) and Cornus sp. (dogwood) was negatively associated

job	file	date	report no.
34-555-031	834.1	July 1, 1987	87-113-K

with the incompatible tree species. This indicates that this shrub group either has an inherent ability to resist tree invasion (which could be used to advantage in the vegetation control program), or it may reflect a difference in habitat preference between these shrub and the tree species. Additional studies are required to differentiate between these possibilities.

TABLE OF CONTENTS

		Page
1.0	INTRODUCTION	1
2.0	METHOD	2
3.0	RESULTS	4
	3.1 Changes in the past 2 years	4
	3.2 Comparison of stems of vegetative and non-vegetative origin	6
	3.3 Species relationships	8
4.0	DISCUSSION	12
5.0	CONCLUSIONS	14
REFERENCES		16
DISTRIBUTION		last page

LIST OF TABLES AND FIGURES

Table		Page
I.	List of woody species at the McCowan Road site.	3
II.	Species density at the McCowan Road right-of-way site.	5
III.	Comparison of stems of vegetative and non-vegetative origin for the major tree species at McCowan Road.	7
IV.	Ordination groupings for the common woody species.	11

Figures

1.	PCA ordination of the common woody species at McCowan Road.	9
2.	MDS ordination of the common woody species at McCowan Road.	10

91601
new 82-10

ontario hydro
research division

To Dr. D. Mills
Director of Research

MCCOWAN ROAD VEGETATION STUDY. THE DEVELOPMENT OF WOODY VEGETATION IN THE SECOND YEAR POST-CLEARING

1.0 INTRODUCTION

The presence of woody vegetation on a right-of-way must be tightly controlled to ensure that the overhead transmission lines are not endangered. An effective control policy must resist the invasion of incompatible species from two diverse sources: the vegetative regrowth of sprouts and suckers from ineffectively treated stumps, and growth originating from non-vegetative sources, such as germinating seeds and advance regeneration. (Advance regeneration refers to seedlings and saplings which were present on the site prior to, but excluded from, the treatment.)

The growth characteristics of the stems will vary considerably, depending on their source. Sprouts and suckers have more vigorous growth rates and a higher survivorship potential than seedlings. The stems which originate from seeds may be more numerous. In addition, the presence of a readily available seed source (the seed bank) and continuous input from neighbouring woodlots act as a constant pressure, which drives the right-of-way succession towards a forest climax. These factors will have a strong bearing on the effectiveness of the various vegetation control options available, thus it is important to determine which source of stems (vegetative or non-vegetative) is potentially more troublesome.

A long term study was initiated in a woodlot near McCowan Road in Markham to assess the natural pattern of vegetative development on a right-of-way. This was designed to simulate the establishment of a new right-of-way and document the vegetational changes which occur. The preclearing conditions at the site were described by Kirby (1984), while the postclearing conditions and sprout development after the first growing season were described by Arron (1985, 1986). Sprout development following the second growing season is described by Brown (1987).

This project was undertaken to compare the densities and height development from stems of vegetative and non-vegetative origin. The possibility that some shrub species at the site are able to suppress the growth of incompatible species (Bramble and Byrnes 1983, Niering and Goodwin 1974) is also considered.

2.0 METHOD

The site consists of a 0.3 hectare (70x42 m) section of a woodlot adjacent to an established right-of-way (north of towers 58 and 59 of the 500 kV Cherrywood to Claireville transmission line). This area was selectively cleared of all incompatible woody species in the fall of 1984. The major tree species removed included 107 Acer saccharum, 97 Populus tremuloides and 94 Fraxinus americana. Nineteen Prunus serotina and 7 Tilia americana were also cut down. The majority of the trees at the site were of seed bearing age, and all but P. tremuloides produce some dormant seeds (Fowells 1965, Kirby 1984). Vegetative reproduction in P. tremuloides is primarily from root suckers, while sprouting from the stump is important in the other four species (Arron 1983). No herbicides were applied to the study site.

The vegetation was surveyed in September of 1986, two growing seasons after clearing. Eleven transects were situated perpendicular to the existing transmission line, at distances of 0, 5, 10, 20, 25, 30, 40, 45, 50, 60 and 65 m from the eastern edge of the study plot. Quadrants of 1x1 m were placed every third meter along the transects. Within each quadrant, the number of stems and the height of the tallest stem for each species of woody vegetation was recorded. Stems of A. saccharum, F. grandifolia, F. americana, P. serotina and T. americana were further separated according to their origin, into vegetative (sprouts) and non-vegetative (seedling and sapling) classes. All stems of P. tremuloides at the site were of vegetative (sucker) origin (Arron, 1985).

Species identifications are according to Soper and Heimburger (1982) and Hosie (1979). A species list is given in Table I.

Species interrelationships were delimited using two ordination techniques, principal components analysis (PCA) and non-metric multidimensional scaling (MDS). Ordination procedures arrange, or order, the data according to the floristic similarities between the quadrants, such that species frequently found in the same quadrants are placed close together on the ordination plot. The methods differ in the mathematical model which is used to reduce the complexity of the data, from the several

Table I. List of woody species at the McCowan Road site

Specific name	Common name
Acer negundo L.	Manitoba maple
Acer saccharum Marsh	sugar maple
Acer spicatum Lam	mountain maple
Carya cordiformis (Wang.) K. Koch	bitternut hickory
Cornus sp. L.	dogwood
Crataegus sp. L.	hawthorn
Fagus grandifolia Ehrh	American beech
Fraxinus americana L.	white ash
Juglans nigra L.	black walnut
Ostrya virginiana (Mill) K. Koch	ironwood
Populus tremuloides Michx	trembling aspen
Prunus pensylvanica L.fil	pin cherry
Prunus serotina Ehrh	black cherry
Prunus virginiana L.	choke cherry
Rhamnus cathartica L.	common buckthorn
Ribes hirtellum Michx	wild gooseberry
Rubus idaeus (Michx) Maxim	wild red raspberry
Rubus occidentalis L.	black raspberry
Tilia americana L.	basswood
Viburnum lentago L.	nannyberry
Viburnum trilobum March	high bush cranberry

interactions which occur in the field (n-1 axes are required to totally explain n variables) to the 2 to 4 dimensions which can be comprehended by the human mind. PCA uses a linear model for the dimension reduction of a standardized correlation matrix derived from the quadrant data. This procedure orders the quadrants such that linear species distributions are obtained. This can lead to severe distortions, as species-environment relationships are seldom linear (Kershaw and Looney 1985). However, this method may be effective over short gradients, where the species response can be approximated by a linear change.

MDS is less subject to distortion, as it assumes a more realistic Gaussian model for the species distributions (Kenkel and Orloci 1986). The MDS algorithm uses an iterative procedure which minimizes the stress between the predicted ordination and the observed distance matrix. A random starting configuration was chosen, using euclidean chord as the distance measure for the species by quadrant matrix (Orloci et al. 1984). Both ordinations were performed on a reduced sample set, where the rare species (frequencies of less than 5%) were excluded from the data (Kershaw and Looney 1985). Species groupings were subjectively selected from the ordination scattergrams.

3.0 RESULTS

3.1 Changes in the past 2 years

Twenty-one species of woody vegetation were identified at the site in 1986, with a total density of 30.45 stems/m^2 (Table II). This is compared with 9 species and a density of 4.53 stems/m^2 reported for the spring of 1985 (Arron, 1985). A rapid proliferation of small shrubs had occurred in the two years following the clearing of the right-of-way. Rubus idaeus had become the most widespread of the species, occurring with a frequency of 70.9% and a density of 5.10 stems/m^2. Prunus virginiana, Cornus sp. and R. occidentalis also formed a major component of the shrub layer, with densities of 8.07, 1.69 and 1.07 stems/m^2 respectively (Table II). This represents an increase of 170-fold for R. idaeus and 85-fold for Cornus sp. between the spring of 1985 and the fall of 1986. P. virginiana and R. occidentalis were not found in the earlier survey (Arron 1985).

Several important changes had also occurred with the tree species. P. tremuloides had undergone a 9-fold increase to become the most abundant species at the site, with a density of 5.16 stems/m^2 and a frequency of 67.3% (Table II). A. saccharum

Table II: Species density at the McCowan Road right-of-way site

Species	Spring 1985 Density[1] units/m^2	Spring 1985 Frequency %	Fall 1986 Density stems/m^2	Fall 1986 Frequency %
Acer negundo			0.01	0.6
Acer saccharum	0.31	25.7	3.69	40.0
Acer spicatum			0.09	5.5
Carya cordiformis			0.01	1.2
Cornus sp.	0.02	1.6	1.69	53.9
Crataegus sp.	0.04	3.3	0.03	1.2
Fagus grandifolia			0.85	6.7
Fraxinus americana	1.16	39.9	2.92	47.3
Juglans nigra			0.01	1.2
Ostrya virginiana	0.003	0.3	0.01	0.6
Populus tremuloides	0.56	27.8	5.16	67.3
Prunus pensylvanica			0.24	13.9
Prunus serotina	2.40	66.8	1.01	17.0
Prunus virginiana			8.07	64.2
Rhamnus cathartica			0.10	5.5
Ribes hirtellum			0.08	2.4
Rubus idaeus	0.03	3.5	5.10	70.9
Rubus occidentalis			1.07	24.2
Tilia americana	0.01	0.9	0.06	2.4
Viburnum lentago			0.13	4.8
Viburnum trilobum			0.08	3.0
Total	4.53		30.45	

1. Data from Arron (1985). Units are the number of clumps of greater than 2 stems plus the number of solitary stems, therefore the stem densities will be underestimated.

was the second most numerous tree (3.69 stems/m^2). F. americana density has doubled to 2.92 stems/m^2, while P. serotina was the only species whose presence declined between the surveys, from the most abundant of all species in 1985 (density of 2.40 stems/m^2, frequency of 66.8%) to a 1986 density of 1.01 stems/m^2 and a frequency of 17%. F. grandifolia had a density of 0.85 stems/m^2. This species was concentrated in the south-west section of the site. Although a few mature F. grandifolia trees were cut during the initial site preparation (Kirby 1984), no seedlings or sprouts of this species were located in the earlier study (Arron, 1985).

3.2 Comparison of stems of vegetative and non-vegetative origin

The contribution of vegetative and non-vegetative growth to the re-establishment of the incompatible trees species is shown in Table III. Seedling and sapling stem densities were greater than vegetative (sprout and sucker) stem densities for all species except P. tremuloides. F. grandifolia stems were entirely of non-vegetative origin, and were all of seedling size (the mean height of the tallest stem in a quadrant was 37.7 cm (Table III)). The relative contribution of seedlings and saplings to total stem density had increased from 60 to 67% in A. saccharum between 1985 and 1986, while it had declined from 95 to 73% in F. americana (Table III, Arron 1985). For P. serotina and T. americana, the stems of non-vegetative origin accounted for approximately 60% of the total density (Table III). However 55% of the total tree stems were of vegetative origin due to the high density of P. tremuloides suckers. This species contributed a sucker density of 5.16 stems/m^2 to a total vegetative stem density of 7.55 stems/m^2 (Table III). The density of all tree stems originating from seed was 6.18 stems/m^2.

The sprouts and suckers on the site were considerably taller than the stems of seed origin in all species except T. americana. In those quadrants in which the species was present, the mean height of the tallest sprouts was 116.7, 114.9 and 201.6 cm for A. saccharum, F. americana and P. serotina respectively, while mean seedling and sapling heights of 64.8, 44.7 and 60.9 were observed (Table III). Although stems of vegetative origin were taller, a higher proportion of the stems of these species originated from seeds. The effect of this frequency difference can be estimated by calculating a mean canopy height on an area basis. Similar canopy heights were observed for seedlings and sprouts of A. saccharum, but the higher seedling

Table III: Comparison of the stems of vegetative and non-vegetative origin for the major tree species at McCowan Road

Species	Non-vegetative density [a]	Non-vegetative height [b]	Non-vegetative height [c]	Vegetative density [a]	Vegetative height [b]	Vegetative height [c]
Acer saccharum	2.49	64.8	25.9	1.20	116.7	25.1
Fagus grandifolia	0.85	37.7	2.3	0	0	0
Fraxinus americana	2.14	44.7	21.1	0.78	114.9	14.9
Populus tremuloides	0	0	0	5.16	189.9	127.8
Prunus serotina	0.64	60.9	10.3	0.37	201.6	7.4
Tilia americana	0.06	75.5	1.9	0.04	57.5	0.1
All stems	6.18	64.2	48.2	7.54	188.3	147.0

a Stems/m^2

b mean height(cm) per occurrence = $\frac{\text{sum of tallest stem in each quadrat}}{\text{number of quadrats with that species}}$

c mean Canopy height (cm/m^2) = $\frac{\text{sum of tallest stem in each quadrat}}{\text{total number of quadrats}}$

frequencies in F. americana, P. serotina and T. americana outweighed the growth advantage of the sprouts, as stems of non-vegetative origin had higher mean canopy heights than stems of vegetative origin for those species. However, the high growth rate and density of the P. tremuloides suckers dominated the total canopy height. Stems of vegetative origin generated a canopy height of 147.0 cm/m^2 while stems of seed origin had a mean canopy height of 48.2 cm/m^2 (Table III).

3.3 Species relationships

The principal components ordination of the 12 common species is shown in Figure 1. The first 3 axes of the PCA account for 67% of the total variance in the data (axis 1 is 37.3, axis 2 is 15.9 and axis 3 is 13.5%). The first axis broadly separates the tree from the shrub species. The shrubs, with the exception of P. virginiana, were positioned near the center of this axis, with scores between -0.2 and 0.3 units. In addition, all five tree species have low loadings on the second axis.

The first two axes separate the species into 3 groups, which are summarized in Table IV. F. grandifolia, A. saccharum and P. virginiana form a tight cluster in the lower right corner of the plot. A second group, consisting of the shrubs R. idaeus, R. occidentalis, Cornus sp. and P. pensylvanica were positioned near the upper middle region of the plot. The third group, consisting of three tree species, (P. tremoloides, P. serotina and F. americana) and two shrub species (A. spicatum and Rhamnus cathartica), have low scores on both the first and second axes. This group was further divided by the third PCA axis, with the trees receiving high scores and the shrubs low scores.

Figure 2 displays the MDS ordination of the common species. Three groupings could be identified, and these were compared to the PCA clusters in Table IV. The first group, with low scorings on axes 1 and 3, and intermediate to high scorings on axis 2, retained the PCA grouping of F. grandifolia, A. saccharum and P. virginiana, and added R. occidentalis. A second group, with intermediate loadings on all 3 axes, consisted of P. pensylvanica, R. idaeus, Cornus sp and P. tremuloides. This is similar to the PCA group 2, with the addition of P. tremuloides and the exclusion of R. occidentalis. The third cluster identified from the MDS ordination, with high loadings on axes 1 and 3, and intermediate scores on axis 2, consisted of P. serotina and F. americana, from group 3B of the PCA analysis. The two species which formed PCA group 3A, R. cathartica and A. spicatum, were not located near any specific cluster and were therefore left out of the groupings. These had the lowest frequency of the common species

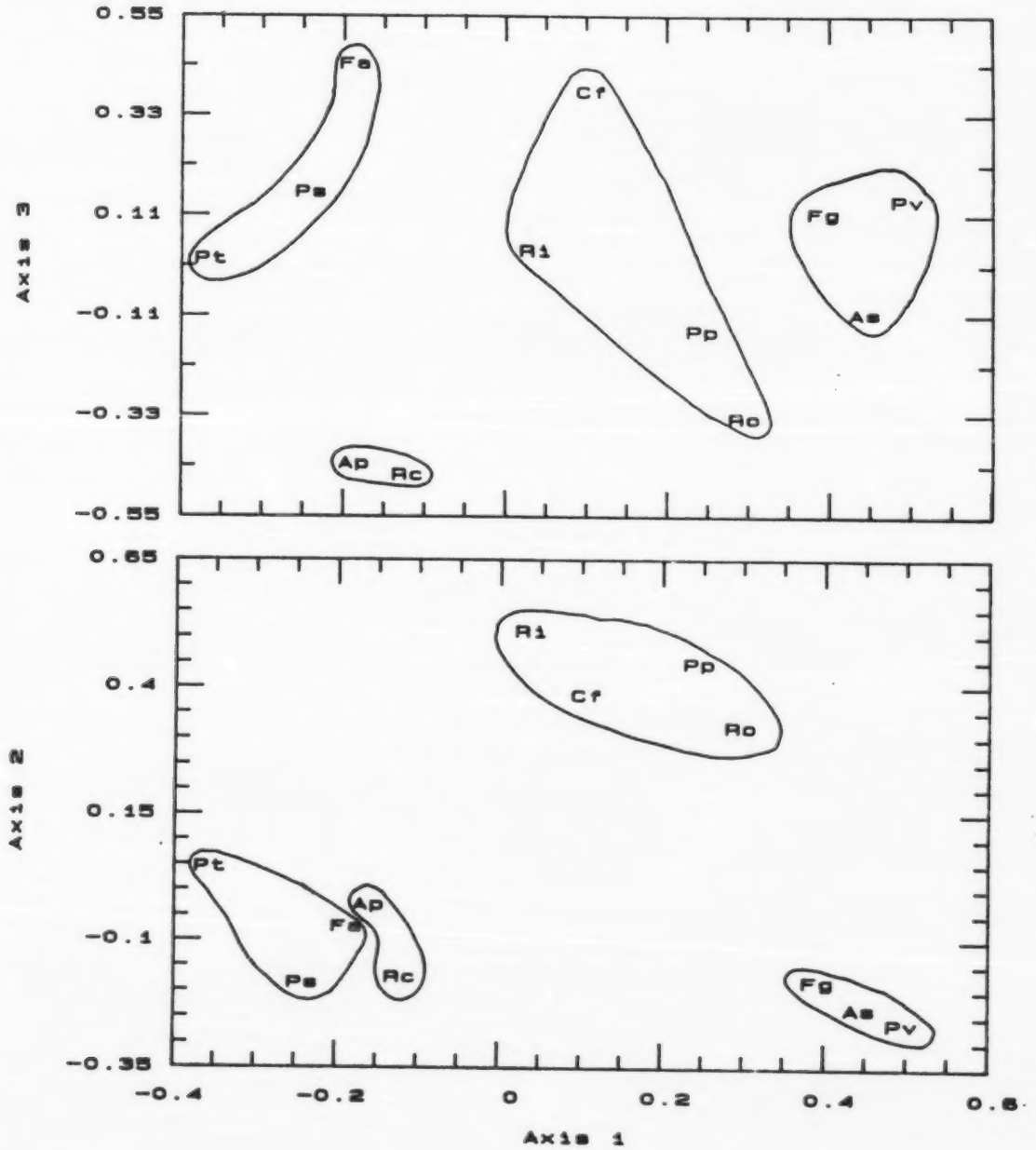

FIGURE 1

PCA ORDINATION OF THE COMMON WOODY SPECIES AT McCOWAN ROAD. THE LOWER FIGURE IS A PLOT OF PCA AXES 1 AND 2, WHILE THE UPPER FIGURE IS A PLOT OF AXES 1 AND 3. SPECIES KEY IS IN TABLE IV

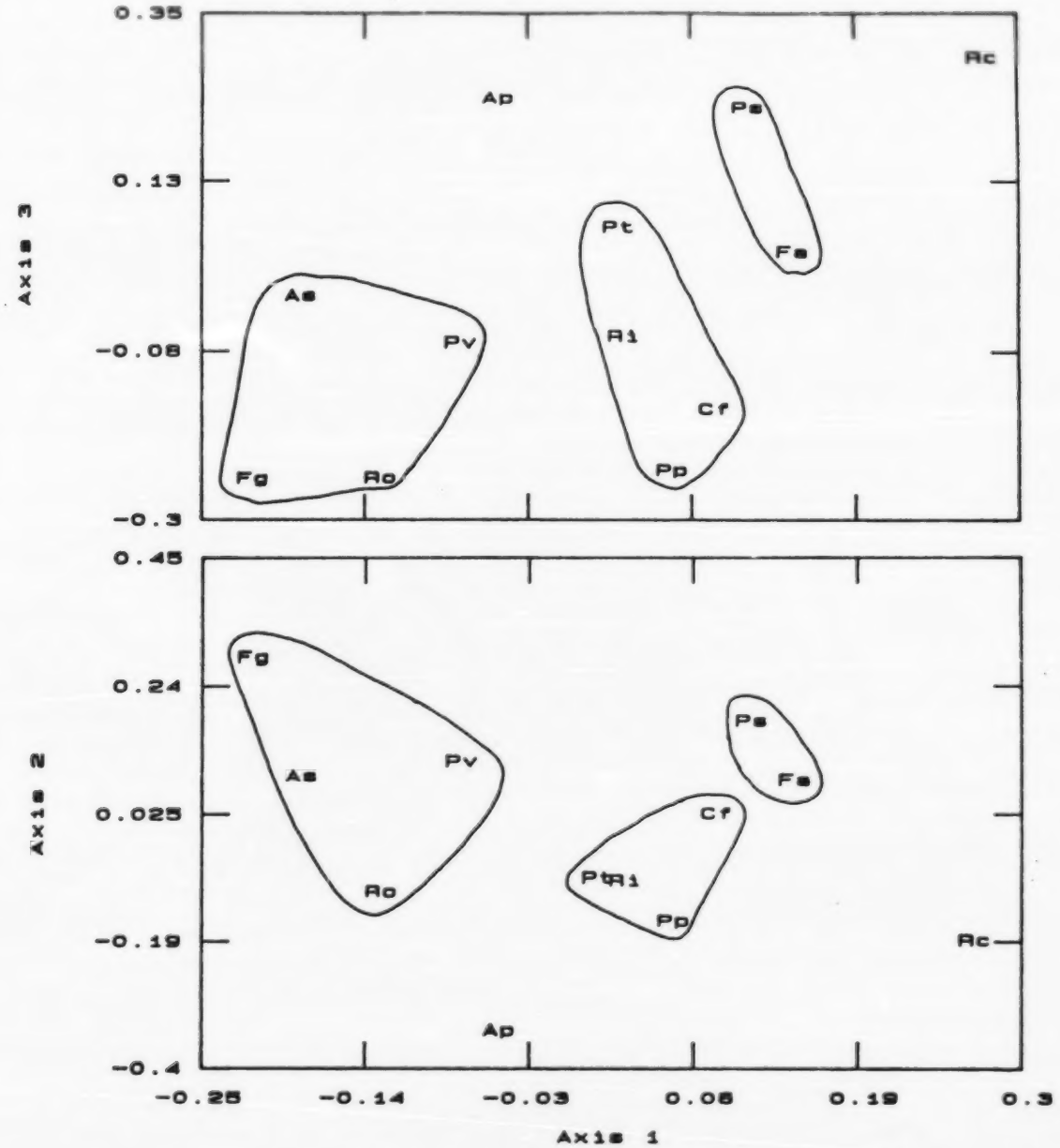

FIGURE 2

MDS ORDINATION OF THE COMMON WOODY SPECIES AT McCOWAN ROAD. THE LOWER FIGURE IS A PLOT OF MDS AXES 1 AND 2, WHILE THE UPPER FIGURE IS A PLOT OF AXES 1 AND 3. SPECIES KEY IS IN TABLE IV

Table IV: Ordination groupings for the common species

Group	Principal Component Analysis	Multidimensional Scaling	Symbol on Figures
1	Prunus virginiana	Prunus virginiana	Pv
	Fagus grandifolia	Fagus grandifolia	Fg
	Acer saccharum	Acer saccharum	As
		Rubus occidentalis	Ro
2	Prunus pensylvanica	Prunus pensylvanica	Pp
	Rubus idaeus	Rubus idaeus	Ri
	Cornus sp.	Cornus sp.	Cf
	Rubus occidentalis	Populus tremuloides	Pt
3A	Rhamnus cathartica		Rc
	Acer spicatum		Ap
3B	Fraxinus americana	Fraxinus americana	Fa
	Prunus serotina	Prunus serotina	Ps
	Populus tremuloides		
		Rhamnus cathartica	
		Acer spicatum	

(Table II), and therefore did not add much information to the distance matrices used in the ordination.

P. serotina and F. grandifolia were located at nearly opposite ends of both ordinations (Figure 1, 2), indicating a strong negative association between these species. This supports a study by Maguire and Forman (1983), who found a negative correlation between seedlings of these species. Similarly, the ordinations show a very strong relationship between A. saccharum and F. grandifolia, which may reflect a large heterogeneity at the site. The southwestern corner of the study plot, adjacent to the right-of-way, had a very sparse cover of tall woody growth. Numerous seedlings of these two species proliferated in this area.

4.0 DISCUSSION

The major source of incompatible stems at the McCowan Road right-of-way site was growth of sprouts and suckers from the stumps of the trees cleared in the fall of 1984. Stems from this source are more numerous and considerably taller than those from seed origin (Table III). P. tremuloides is by far the most important species in this respect. This is the only tree species on the site which regularly reproduces by sucker formation (Fowells 1965), and the increase in this process as a response to cutting is adequate to restock a stand (Harniss and Bartos 1985). This species is very intolerant of shade (Fowells 1965, Hosie 1979) and the clearing of the area would produce conditions which are highly favourable for its growth.

The importance of vegetative reproduction has been emphasized in several right-of-way studies (Allsbrooks et al. 1984, Bramble et al. 1984, Dreyer and Niering 1986). The vigorous growth, a consequence of an established root system with its associated water supply and carbohydrate reserves, produced stems which were considerably taller than the respective growth from seeds (Table III). For species such as A. saccharum and F. americana, where the seedlings are more numerous than sprouts (Table III), it becomes a question of whether the increase in numbers outweigh the more vigorous sprout growth. Regeneration of forest stands by these species is dependent upon seedlings and advance regeneration (Powell and Tryon 1979, Goldsmith and Lees 1982, Ross et al. 1986), suggesting that stems from seed origin will be potentially more troublesome on a right-of-way.

The source of the problem stems will also depend on the vegetation control method in use. The frequency of the treatment cycle is a function of the fastest growing stems, which would be of vegetative origin at this site (Table III). If non-selective treatments are used, such as mowing or blanket herbicide sprays, stem density may not be an important factor (Johnston 1984). However, vigorous sprout and sucker growth may cause problems, as these stems are more likely to be too large to treat without special handling methods (Allsbrooks et al. 1984). The time required for selective treatments will be a function of stem density. In this situation the more numerous seedlings and saplings represent a larger time commitment. Additionally, their smaller stature and more random distribution will increase the possibility of some stems being overlooked, when compared to the taller sprout clumps.

The greatest changes in stem density on the site have occurred within the shrub community. There has been a significant increase in species typical of open, recently disturbed areas, such as Rubus sp., Cornus sp., P. virginiana and P. pensylvanica (Table II). An important question arises as to what influence these shrubs will have on the growth of the incompatible tree species. Several reports suggest that a dense layer of shrub or herbaceous vegetation will inhibit the establishment of tree seedlings (Pound and Egler 1953, Niering and Egler 1955, Maguire and Forman 1983), while others have found no such relationship (Dunn 1986). Niering and Goodwin (1974) suggest that vegetation control management techniques which selectively remove the incompatible trees, but maintain the shrub layer intact, should lead to the development of a community which would require minimal maintenance. Such treatments select for species which favour vegetative reproduction, through rhizomes and root suckering (Bramble et al. 1984) and thus form dense patches which may inhibit seedling establishment and out-compete those seedlings that do establish (Bramble and Byrnes 1976).

Several studies suggest that the formation of a stable shrub community is possible (Pound and Egler 1953, Niering and Egler, 1955, Niering and Goodwin 1974, Bramble and Byrnes 1976, 1983; Dreyer and Niering 1986), however the species involved differ considerably from those present at the McCowan Road site. The species interactions at the site are depicted in the ordination plots. In the PCA analysis, a group of shrubs, consisting of Cornus sp., P. pensylvanica, R. idaeus and R. occidentalis, were separated from the trees and other shrubs by the second axis (Figure 1).

The MDS ordination did not produce as clear a separation, as P. tremuloides was located in the center of this group, near R. idaeus (Figure 2). These are the two most frequently occurring species (Table II), with 48% of the quadrats containing both plants. Therefore it could be expected that these species would be placed in the centre of the ordination, with the other members of the shrub group (Cornus sp. and P. pensylvanica) associated with R. idaeus but not P. tremuloides. This separation, or negative association, between the shrub group and the trees indicates a difference in habitat preference. The shrubs are characteristic of woodland clearings and disturbed areas, while the tree seedlings are able to grow under a canopy (Fowells 1965, Hosie 1979, Soper and Heimburger, 1982). However, another possibility, that the shrubs are interfering with tree seedling establishment, cannot be discounted. Further investigation is required to evaluate the role of these shrub species in generating a stable, low canopy cover.

5.0 CONCLUSIONS

1. The stems originating from sprouts and suckers are more numerous and taller than stems originating from seeds at the McCowan Road site.

2. Suckers of P. tremuloides represent the majority of the vegetative stems, and accounted for a large component of the canopy height. Stems of other tree species were predominantly of seed origin.

3. There was a negative association between one group of shrubs and the tree species. Further studies are necessary to evaluate the possible role that these shrub species may play in the development of a stable, low canopy cover.

Approved by:

M.R. Booth
Acting Manager
Chemical Research Dept

Prepared by:

D.G. Brown
Biologist
Biological Research Section

Reviewed by:

G.T. Haymes
Acting Supervising Biologist
Biological Research Section

DGB:msf

REFERENCES

Allsbrooks, D.W., D.K. Fowler and L.J. Fowler. 1984. Evaluation of woody vegetation on new transmission line rights-of-way. IN: A.F. Crabtree (ed) Proceedings of the 3rd international symposium on environmental concerns in right-of-way management. Mississippi State University Press. p 330-341.

Arron, G.P. 1983. Factors affecting stump sprouting and root suckering in woody species. Ontario Hydro Research Division Report 83-234-K.

Arron, G.P. 1985. Progress report: McCowan Road right-of-way study. Post-clearing conditions. Ontario Hydro Research Division Report C85-115-K.

Arron, G.P. 1986. Progress report: McCowan Road right-of-way study. Stump sprouts after one growing season. Ontario Hydro Research Division Report C86-7-K.

Bramble, W.C. and W.R. Byrnes. 1976. Development of a stable, low plant cover on a utility right-of-way. Proceedings of the 1st international symposium on environmental concerns in right-of-way management. Mississippi State University Press. p. 168-176.

Bramble, W.C. and W.R. Byrnes. 1983. Thirty years of research on development of plant cover on an electric transmission right-of-way. Journal of Arboriculture 9,67-74.

Bramble, W.C., W.R. Byrnes and P.A. Johnston. 1984. Right-of-way vegetation produced by aerial, selective basal and ground foliar herbicide applications. IN: A.F. Crabtree (ed) Proceedings of the 3rd international symposium on environmental concerns in right-of-way management. Mississippi State University Press. p. 380-388.

Brown, D. 1987. Progress report. McCowan Road right-of-way study. Stump sprouting and suckering in the second growing season. Ontario Hydro Research Division Report C86-85-K.

Dreyer, G.D. and W.A. Niering. 1986. Evaluation of two herbicide techniques in electric transmission rights-of-way: development of relatively stable shrublands. Environmental Management 10, 113-118.

Dunn, C.P. 1986. Shrub layer response to death of Ulmus americana in southeastern Wisconsin lowland forests. Bulletin of the Torrey Botanical Club 113, 142-148.

Fowells, H.A. 1965. Silvics of forest trees of the United States. USDA Forest Service, Agricultural Handbook #271. Washington, D.C.

Goldsmith, F.B. and Lees, J.C. 1982. Regeneration and management of white ash in Nova Scotia and New Brunswick. Forestry Cronicle. February 1982, 35-39.

Harniss, R.O. and D.L. Bartos. 1985. Survey of Aspen stands treated with herbicides in the western United States. USDA Forest Service #INT-340.

Hosie, R.C. 1979. Native trees of Canada. Canadian Forestry Service, Ottawa.

Johnston, P.A. 1984. Cost comparison of right-of-way treatment methods. ESEERCO Research Report EP80-5.

Kenkel, N.C. and L. Orloci. 1986. Applying metric and nonmetric multidimensional scaling to ecological studies: some new results. Ecology 67, 919-928.

Kershaw, K.A. and J.H.H. Looney. 1985. Quantitative and dynamic plant ecology. 3rd ed. Edward Arnold, London.

Kirby, M.K. 1984. McCowan Road right-of-way study. Preclearing conditions. Ontario Hydro Research Division Report C84-86-K.

Maguire, D.A. and R.T.T. Forman. 1983. Herb cover effects on tree seedling patterns in a mature hemlock-hardwood forest. Ecology. 64, 1367-1380.

Niering, W.A. and Egler F.E. 1955. A shrub community of Virburnum lentago, stable for twenty-five years. Ecology 36, 356-360.

Niering, W.A. and Goodwin, R.H. 1974. Creation of relatively stable shrublands with herbicides: arresting "succession" on rights-of-way and pastureland. Ecology 55, 784-795.

Orloci, L., N.C. Kenkel and P.H. Fewster. 1984. Probing simulated vegetation data for complex trends by linear and non-linear ordination methods. Abstracta Botanica 8, 163-172.

Powell, D.S. and E.H. Tryon. 1979. Sprouting ability of advanced growth in undisturbed hardwood stands. Canadian Journal of Forest Research 9, 111-120.

Pound, C.E. and Egler, F.E. 1953. Brush control in southeastern New York: fifteen years of stable tree-less communities. Ecology 34, 63-73.

Ross, M.S., Sharik, T.L. and Smith, D.W., 1986. Oak regeneration after clear felling in southwest Virginia. Forest Science 32, 157-169.

Soper, J.H. and M.L. Heimburger. 1982. Shrubs of Ontario. Royal Ontario Museum, Toronto.

DISTRIBUTION

Dr. D. Mills — Director of Research
Mr. S.T. Griffiths — Transmission Operations, U8A5
Mr. B.M. Allen — Transmission Operations, U8B1
Mr. W.B. Cormack — Distribution Operations, U6A1
Mr. G.T. Haymes — Chemical Research
Mrs. R.A. Nakrosius — Chemical Research
Dr. G.P. Arron — Chemical Research
Dr. D. Brown (3) — Chemical Research

Public Reference Centre
Editorial Section (2)
Office Copies (3)
Extra Copies (3)

- last page -

87-113